
Sarocalamus, a New Sino-Himalayan Bamboo Genus (Poaceae: Bambusoideae)

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ABSTRACT. *Sarocalamus* Stapleton, a new genus distributed from the eastern Himalayas to the Sichuan Province of China, is described. Among all Asian bamboo genera it shares the greatest number of morphological characters with the North American genus *Arundinaria* Michaux. However, DNA sequencing has suggested that other genera are probably more closely related to *Arundinaria*, while *Sarocalamus* appears instead to be a possible sister group to *Phyllostachys* Siebold & Zuccarini, a genus with some similarities in branching but very different flowers. Biogeographical implications are discussed, and the new combinations *Sarocalamus racemosus* (Munro) Stapleton, *S. faberi* (Rendle) Stapleton, and *S. spanostachyus* (T. P. Yi) Stapleton are made.

Key words: *Arundinaria*, Bhutan, biogeography, China, India, Nepal, North America, *Sarocalamus*.

Characterization of the Asian temperate woody bamboos for the *Flora of Bhutan* (Stapleton, 1994, 2000) and the forthcoming English-language version of the *Flora of China* has established that three species of Sino-Himalayan bamboo are morphologically most similar to the geographically distant type species of *Arundinaria* Michaux, *A. gigantea*, from the southeastern United States (Texas to Maryland). One species, *Arundinaria racemosa* Munro, is from eastern Nepal, the Indian States of West Bengal and Sikkim, and Bhutan. The others, *Arundinaria faberi* Rendle and *Bashania spanostachya* T. P. Yi, are from isolated mountains in southern Sichuan Province, and northeastern Yunnan Province, Southwest China. *Bashania fansipanensis* T. Q. Nguyen from northern Vietnam may also belong in this genus, but is not well known.

Apart from *Sarocalamus*, all other Asian bamboos can be separated clearly from the type species of *Arundinaria* on the basis of floral or vegetative morphological characters. This includes species in

the genus *Pleioblastus* Nakai, which is still frequently synonymized within *Arundinaria* but differs in its fused prophyll margins (Stapleton, 1997). Although more than 500 species names have been published in *Arundinaria*, only four, poorly known Asian species do not already have combinations in other genera and a different, modern placement (Ohrnberger, 1999). More than 30 Asian genera have been described by Japanese, Chinese, and European botanists to accommodate species originally described in *Arundinaria*, and the number of genera currently recognized in this group ranges from 19 (Li, 1997) to 28 (Wang, 1997). In a moderate treatment Ohrnberger (1999) included 23 genera. Although the circumscription of *Arundinaria* has remained controversial, with the number of Asian species included in the genus by different authors ranging from 16 (Chao & Chu, 1981) to none (Wang, 1997; Keng & Wang, 1996; Ohrnberger, 1999), it is clear that a large number of temperate Asian genera are now recognized as being distinct from that genus.

Asian bamboos morphologically closest to the North American type species, *Arundinaria gigantea*, such as species of *Sarocalamus*, *Pleioblastus*, and *Bashania* P. C. Keng & T. P. Yi, are often still included in *Arundinaria* (Clayton & Renvoize, 1986; Chao & Renvoize, 1989; Li, 1997). However, molecular evidence from ITS, *trnL* intron, *trnL-F* intergenic spacer, and *rpl16* intron DNA sequence data (Zhang, 1996; Ní Chonghaile, 2002) has suggested that such species are not necessarily its closest relatives. Instead, *Pseudosasa japonica* (Steudel) Nakai has been suggested as the closest Asian relative of *Arundinaria gigantea* from both *ndhF* and *rpl16* sequence data (Zhang, 1996; Ní Chonghaile, 2002), a clade comprising *A. gigantea* and *P. japonica* receiving 86% BS (Ní Chonghaile, 2002), even though *P. japonica* has never been con-

sidered a particularly close relative of *A. gigantea* on morphological grounds. *Pseudosasa* Nakai has received almost universal recognition (McClure, 1973; Clayton & Renvoize, 1986; Chao, 1989; Demoly, 1996; Keng & Wang, 1996).

Although *Sarocalamus* shares the principal discreet macro-morphological character states with *Arundinaria*, it still differs in several, more quantitative characters. These include shorter, more cylindrical, more separated and less imbricate florets of more consistent size, less than 10×2 mm; a more sinuous rhachilla with much longer internodes; completely glabrous pedicels; and more delicate, smoother, rugose rather than ribbed, less closely spaced leaf blades. The three species of *Sarocalamus* have been placed in four other Asian genera when not included in *Arundinaria*: *Fargesia* Franchet, *Yushania* P. C. Keng, *Bashania*, and *Gelidocalamus* T. H. Wen. *Sarocalamus* differs quite profoundly from *Fargesia* and *Yushania* in having pachymorph rather than leptomorph rhizomes. It is closer to *Bashania* and *Gelidocalamus*. However, while those genera do have leptomorph rhizomes, they also have decurrent, strongly pulvinate synflorescence paraclades, and a much greater degree of compression of the basal internodes on their central branches, giving a higher number of branches at each culm node. *Bashania* also has thickened, prominent, long-ciliate prophyll keels, greater branchlet ramification and tougher leaves, while *Gelidocalamus* has much smaller florets, compressed rhachillas, swollen supra-nodal ridges, solitary, more lanceolate leaves, and its 7 to 12 subequal branches do not re-branch at all.

Molecular evidence is generally lacking at the generic level in Asian woody bamboos, with low or absent support for many well-recognized taxonomic groupings. Combined analyses of data from different genes is starting to provide slightly better resolution, however. What support has been shown at the generic level is generally congruent with morphological distinctions and current taxonomic treatments of Asian bamboos. In the most comprehensive study of woody bamboos (Ní Chonghaile, 2002), one species of *Sarocalamus* was included along with *Arundinaria gigantea*, species of *Bashania*, *Fargesia*, *Yushania*, and 33 other genera. While the two species of *Bashania*, *B. fargesii* (E. G. Camus) P. C. Keng & T. P. Yi and *B. qingchengshanensis* P. C. Keng & T. P. Yi, formed a fairly well-supported clade (70% BS in parsimony analysis, 82% BS in NJ analysis), *Sarocalamus faberi* (included there as *Bashania fangiana* (E. G. Camus) P. C. Keng & T. H. Wen) was not resolved within the *Bashania* clade and did not associate

with any other genera in parsimony analysis. It remained a largely unresolved member of the well-supported monophyletic group of mainly Asian temperate bamboos first reported by Watanabe et al. (1994). It is now known to include 25 or more genera from Africa, Asia, and North America adapted to subtropical or temperate habitats in both hemispheres (Ní Chonghaile, 2002), but is widely referred to as the "north temperate clade."

The generic name *Sarocalamus* means broom bamboo and is derived from *saron* (σάρων: broom, sweepings) and *calamus* (καλαμὸς: reed, bamboo). It alludes to the very erect branching, reminiscent of a traditional broom or besom, and the frequent use of these bamboos for sweeping.

Sarocalamus Stapleton, gen. nov. TYPE: *Sarocalamus racemosus* (Munro) Stapleton.

Bashaniae et *Arundinariae* rhizomatibus tenuibus, staminibus 3, inflorescentia ebracteata, gemmis apertis similis, ab illa ramis inflorescentiae erectis, internodiis ramorum longioribus, foliis tenuibus, ab hac flosculis angustis, ab uterque pedicellis glabris, differt.

Similar to *Bashania* and *Arundinaria* in its leptomorph rhizomes, 3 stamens, ebracteate inflorescences and open buds. Differing from the former in its erect inflorescence branches, longer branch internodes and thinner leaves, from the latter in its narrower florets, and from both in its glabrous pedicels.

Temperate self-supporting bamboo; rhizomes leptomorph; culms tillering (pluricaespitose), erect to drooping; internodes smooth, terete; nodes not swollen, unarmed; supra-nodal ridge well developed; branch buds lanceolate, on promontory, enclosed within single, 2-keeled prophylls, always open at the front; branches initially 1 to 3, very erect, appressed, sulcate, basal internodes progressively increasing in length, basal internode often long, lateral branching often distant from culm; complement proliferating to become broom-like, attenuate; lateral branch axes always subtended by sheaths, no replication of lateral branches. Leaf blades linear-lanceolate, thin, less than 12 cm long, with prominent cross-veins (tessellate). Synflorescence initially terminal or lateral to leafy branches, later in leafless complements; synflorescence branches glabrous, without pulvini, remaining very erect and appressed, branching racemose or rarely partially paniculate, not fasciculate, subtended by very small remnants of sheaths or rings of hairs, rarely with very small pulvini. Spikelets 3 to 6 per synflorescence, on glabrous promontory (pedicel); prophyll represented by lower glume; glumes 1 to 2, both small, lower glume usually very small, usu-

ally distant from lower lemma, without subtended buds (flowering semelauctant); rhachilla often sinuous, strongly flattened, more than half length of palea; palea keels curving, appressed to rhachilla; stamens 3; stigmas 3. Flowering gregarious.

Distribution. East Nepal, India (West Bengal & Sikkim), Bhutan, Western China (Tibet, Sichuan and Yunnan Provinces), North Vietnam, 2800–3900 m.

1. *Sarocalamus racemosus* (Munro) Stapleton, comb. nov. Basionym: *Arundinaria racemosa* Munro, Trans. Linn. Soc. London 26: 17. 1868, emend. Gamble in Kew Bull. Misc. Inform. 1912: 138. 1912. *Fargesia racemosa* (Munro) T. P. Yi, J. Bamboo Res. 2(1): 39. 1983. *Yushania racemosa* (Munro) R. B. Majumdar, in S. Karthikeyan et al., Fl. Ind. Enumerat.–Monocot.: 283. 1989. TYPE: Nepal/Sikkim (India). Islumbo Pass [Chiya Banjyang], 13 Oct. 1857, Thomson s.n., Kew distribution number (K 6738) (lectotype, selected by Gamble (1912: 137), K).

Arundinaria racemosa Munro was first described from collections of two species from the eastern Himalayas (Munro, 1868). It was emended by Gamble (1912), who separated the lower altitude collections from 6000 to 9000 ft. in the vicinity of Darjeeling into a new species, *Arundinaria maling*, now known as *Yushania maling* (Gamble) R. B. Majumdar, leaving only the “high-level form,” found above 10,000 ft., in *Arundinaria racemosa*. The Munro syntypes were discussed in detail by Gamble (1912: 137) when describing his new species. He stated “it seems quite evident that Thomson’s Islumbo Pass flowering specimen is the real type of *A. racemosa*.” This can be taken as an effective lectotypification under Article 7.11 of the *St. Louis Code* (Greuter et al., 2000), as a type element was indicated by direct citation including the term “type.” Chao and Renvoize (1989) later designated Munro’s first syntype, a Thomson collection made in 1857 from 6000 ft. on Birch Hill in Darjeeling, as lectotype of *A. racemosa*. They apparently did not realize that the species had already been lectotypified by Gamble, even though they concurrently lectotypified *A. maling*, in the protologue of which Gamble had made his lectotypification of *A. racemosa*. According to the label of Thomson’s Birch Hill collection, the lectotype designated by Chao and Renvoize was a “pale blue” bamboo. Two bamboos from Darjeeling, *A. maling* and the rarer *Himalayacalamus hookerianus* (Munro) Stapleton, both have pale blue culms, while culms of *A. ra-*

cemosa are green or yellow. Gamble (1912: 137) had even stated that “Birch Hill is the end of the Darjeeling Ridge . . . and is a very unlikely locality for the high-level *A. racemosa*.” However, as Gamble (1912: 137) had also pointed out, Thomson’s collection of some other, pale blue bamboo truly from Birch Hill would seem to have become lost, and the Birch Hill label is currently attached to a sheet bearing only a flowering specimen from Islumbo Pass, which bears the correct label as well. It would appear, therefore, that Chao and Renvoize (1989), by simply designating Munro’s first syntype as lectotype, may have inadvertently designated a long-lost collection of *A. maling* or *Himalayacalamus hookerianus* from Darjeeling as lectotype of *A. racemosa*, but fortunately there can be no doubt that the earlier lectotypification of Gamble (1912) takes priority. The Islumbo Pass material shows the distinctive branching and synflorescence of *Sarocalamus* and is accepted here as lectotype of *A. racemosa* Munro and type of the genus *Sarocalamus*. It was collected by Thomson in 1857 in woods above the Islumbo Pass, now known in Nepali as *Chiya Banjyang*, on the Singalila Range, which separates East Nepal and Sikkim. The name *Arundinaria racemosa* is still often misapplied to *Arundinaria maling* Gamble in India (Tewari, 1993; Seethalakshmi & Muktesh Kumar, 1998), even though that species has been transferred by the Botanical Survey of India as *Yushania maling* (Gamble) R. B. Majumdar.

Habitat and distribution. *Sarocalamus racemosus* is found at an altitude of 2900–3800 m in the understory of *Abies densa* and mixed coniferous and rhododendron forests, in degraded forest, and in cleared areas of pastureland, in which it can be the principal species. It is often found on more freely drained sites than *Yushania microphylla*, which has hollow rhizomes and extends to a higher altitude. The type collection was made on a pass that constitutes the border between Nepal and Sikkim. Further collections have been made in Sikkim, where it was reported to be common in forests around Senchal (Gamble, 1896), and across western, central, and eastern Bhutan. It is to be expected that it will also be found in further localities in the easternmost districts of Panchtar and Taplejung in Nepal. It has also been reported from Tibet (Yi, 1983) and is to be expected in the Indian State of Arunachal Pradesh.

Additional specimens examined. INDIA. **Sikkim:** Singalila Range, Sukumbum, May 1889, *Dr. Gammie’s Collectors s.n.* (K). BHUTAN. **Paro:** Chile La, 4 June 1971, *Bedi 32* (K); Thimphu: Dorchula, 22 Dec. 1989 *Stapleton 872* (THIM). **Tongsa:** Yotong La, 15 Aug. 1989, *Stapleton*

852 (THIM). **Bumthang:** Lame Gumpa, 23 June 1990, *Bürgi s.n.* (K, THIM). **Mongar:** Thrumsingla, 11 Oct. 1990, *Wood 7348* (E). **Trashigang:** Tashiyangtse, E side of Pang La, 7 June 2000, *G. & S. Miehe 00-092-03* (THIM).

2. *Sarocalamus faberi* (Rendle) Stapleton, comb. nov. Basionym: *Arundinaria faberi* Rendle, J. Linn. Soc. 36: 435. 1904. *Sinarundinaria faberi* (Rendle) P. C. Keng, Techn. Bull. Nat. For. Res. Bur. China, No. 8 (Prelim. Stud. Chin. Bamb.): 13. 1948. *Bashania faberi* (Rendle) T. P. Yi, J. Bamboo Res. 12(2): 52. 1993. TYPE: China. Sichuan: above Chungking, Yangtzekiang, *E. Faber 1119* (holotype, K).

Arundinaria racemosa subsp. *fangiana* A. Camus, J. Arnold Arbor. 11: 192. 1930. Basionym: *Sinarundinaria fangiana* (Camus) P. C. Keng, Techn. Bull. Nat. For. Res. Bur. China, No. 8 (Prelim. Stud. Chin. Bamb.): 13. 1948. *Gelidocalamus fangianus* (A. Camus) P. C. Keng & T. H. Wen, J. Bamboo Res. 2(1): 20. 1983. *Bashania fangiana* (A. Camus) P. C. Keng & T. H. Wen, J. Bamboo Res. 4(2): 17. 1985. TYPE: China. Sichuan: Mt. Omei, 15 Aug. 1920, *W. P. Fang 3002* (holotype, P not seen).

Additional material. CHINA. **Sichuan Province:** Omei Shan, 19 July 1925, *Sewell 1* (K); Wolong, Wuyipeng, Nov. 1981, *Halle s.n.* (K); Tiantai Shan, 19 July 1989, *J. P. Ruan 890004* (K). **Yunnan Province:** Dungchuan (living collection 'Tung Chuan No 2' cultivated in Europe & US), Germany, Stockdorf, *Riedelsheimer s.n.* (K); UK, Pulborough, *Addington s.n.* (K).

3. *Sarocalamus spanostachyus* (T. P. Yi) Stapleton, comb. nov. Basionym: *Bashania spanostachya* T. P. Yi, Acta Bot. Yunnan. 11: 35. 1989. TYPE: China. Sichuan: Huili Xian, Beimu Shan, 3200–3900 m, 18 May 1987, *Yi Tongpei 87249* (holotype, SIFS not seen).

Distribution. Sichuan Province, China.

DISCUSSION

The phylogenetic relationships of *Sarocalamus* remain unclear, although it is evidently a member of the "north temperate clade." Neighbor Joining analysis of combined plastid and nuclear sequence data (Ní Chonghaile, 2002) gave moderate bootstrap support (76%) for a clade comprising *Sarocalamus faberi* (included there as *Bashania fangiana*) and *Phyllostachys flexuosa* (Carrière) A. & C. Rivière, although this clade was not resolved in parsimony analysis. *Sarocalamus* shares simple branching with *Phyllostachys*, but has ebracteate rather than bracteate synflorescences. It also shares other branching characters with *Phyllostachys*, including open, 2-keeled prophylls, presence of a supra-nodal ridge, and substantial sulcation of inter-

nodes above the branches. If further investigations support this very tentative placement as sister group to *Phyllostachys*, it could indicate that vegetative characters such as those associated with branching may be at least as phylogenetically informative as a synflorescence type.

As species of *Sarocalamus* share so many discrete morphological character states with the North American species *Arundinaria gigantea*, it is interesting to consider their possible relationships. Ecological and biogeographical considerations would suggest that bamboos endemic to well-drained, high-altitude, cold-temperate forest understory habitats in Sino-Himalayan mountains are unlikely to be congeneric with those found in and around the swamps of the southeastern United States. Their infrequent, cyclical flowering and short-lived seed that is not adapted for dispersal by any agent would appear to lead to limited ability to spread. Cheplick (1998) reported that even grass seed specifically adapted for wind dispersal is rarely carried more than a few meters. Spread of temperate bamboo species probably relies as much on underground extension of rhizomes as on seed dispersal, and it would seem reasonable to expect smaller average natural range sizes for montane bamboos compared to grasses in general. Clark (2001) reported a much higher degree of endemism (87%) in woody Andean bamboos than in other grasses, increasing with altitude, which she considered attributable to isolation among other factors. Bystriakova et al. (2003), studying the distribution of all Asian woody bamboos, reported that 45% have areas of potential occurrence small enough for them to be of conservation concern by IUCN criteria. Several Asian bamboos are quite widely distributed, but those Asian species with the broadest geographic ranges are mainly tropical species of high utility, such as *Bambusa vulgaris* Schrader ex Wendland, suggesting that recent anthropogenic influences could be involved in their distribution patterns.

Unless long-distance dispersal of bamboo seed occurred somehow across East Asia, the Pacific, and North America, it would appear that the ancestors of *Arundinaria gigantea* crossed the Bering Straits land bridge from Asia before the Straits opened, an event dated between 5.4 and 5.5 million years ago (Gladenkov et al., 2002). They would have since become isolated from all Asian relatives such as ancestors of *Sarocalamus*, presumably as a result of a combination of global cooling, rising sea levels, and ice epochs. For such temperate bamboos with flowering cycles of up to a century or more and no seed dispersal mechanism, but lep-

tomorph rhizomes with an annual spreading capability of up to 2 m, it would seem reasonable to expect average sustained migration in any one direction in the order of only 100 m per century. As *Arundinaria gigantea* is currently found about 5–7000 km from the Bering Straits, and only one species of temperate clade bamboo is found on the American continents, this would be consistent with bamboo just entering Alaska before the Straits opened and the land bridge closed. With species of *Sarocalamus* located 6–8000 km to the southwest of the Bering Straits, it could be conjectured that common ancestors of *Arundinaria* and *Sarocalamus* diverged up to twice as long ago, in the order of 10 mya. It would appear from the failure of *Sarocalamus* and *Arundinaria* to be resolved as a separate clade in molecular data produced so far, despite their morphological similarities, that a vicariance event 5–10 mya was sufficiently distant for subsequent evolution to have obscured true relationships, and for the morphological similarities between the genera to be homoplasious or symplesiomorphic.

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